A low-cost versatile system for continuous real-time respiratory activity measurement as a tool in environmental research

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Introduction

The release of carbon dioxide from soil due to biological activity reflects the interplay of added and sequestered organic matter and the fraction that is being biologically decomposed (Solvita, 2016). To evaluate the ResTox system's performance in quantifying soil respiration, the experimental results were compared with those obtained using the Solvita test system. The Solvita test system is a commonly used cost effective commercial soil respiration method implemented by laboratories and soil scientists worldwide. The Solvita respiration test system employs thin-layer gel chromatography for evaluating the quantity of CO_2 released by microbes after soil wetting, during a 24-hour test period. The gel probe color is then read spectrometrically using the DCR (Digital Color Reader).

Experimental procedure

The Solvita soil respiration test was performed according to the CO_2-Burst Protocol (SOP) provided in the official Solvita manual (Solvita, 2016). 40 g of dried and coarse-sieved (2 mm) soil was added to the graduated beaker provided in the kit. To reach 50% of pore space, 10 mL of DI water was dispensed onto the soil sample. This step denoted the start of the soil respiration test, i.e. the insertion of the gel CO_2 probe and closing the jar for 24 hours. The test was performed under stable temperature conditions, at 23 °C. The color result (CO_2-C level expressed in mg kg^{-1} (ppm)) was measured after 24 hours, using the DCR device provided in the kit.

The test procedure involving the ResTox system followed the soil sample preparation and wetting steps described above. Particular attention was paid to performing experiments in vessels of the same volume as in the Solvita test. CO_2 release from the test soil was continuously monitored and recorded during a 24-hour interval, with a resolution of 0.5 min. At the end of the test, CO_2 production and average CO_2-production rate were calculated.

For comparison purposes, the results obtained using the Solvita system (in mg kg^{-1} (ppm) CO_2-C / 24 h) were converted into the unit of measurement of the ResTox system (mg kg^{-1} (ppm) CO_2 / 24 h) based on the molar mass ratio of CO_2 and CO_2-C.

Figure 1: Soil respiration evaluated using low-cost methods (Solvita soil respiration system and the ResTox respiratory activity measuring system).

Experimental results

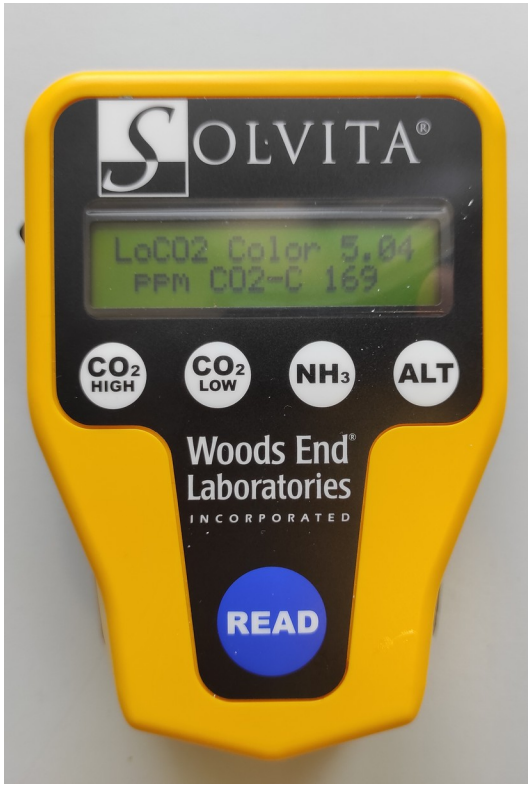

Figure 2: Example of CO_2 respiration data using the Solvita test system.

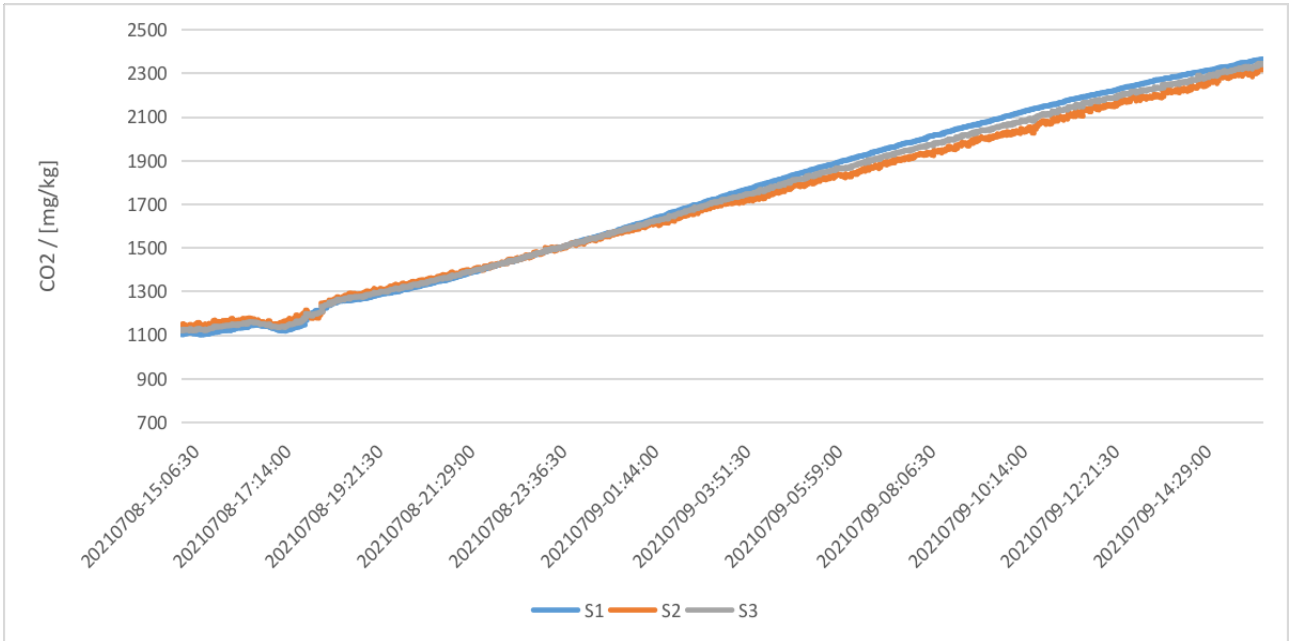

Figure 3: Raw outputs of the ResTox system during a 24-h test period.

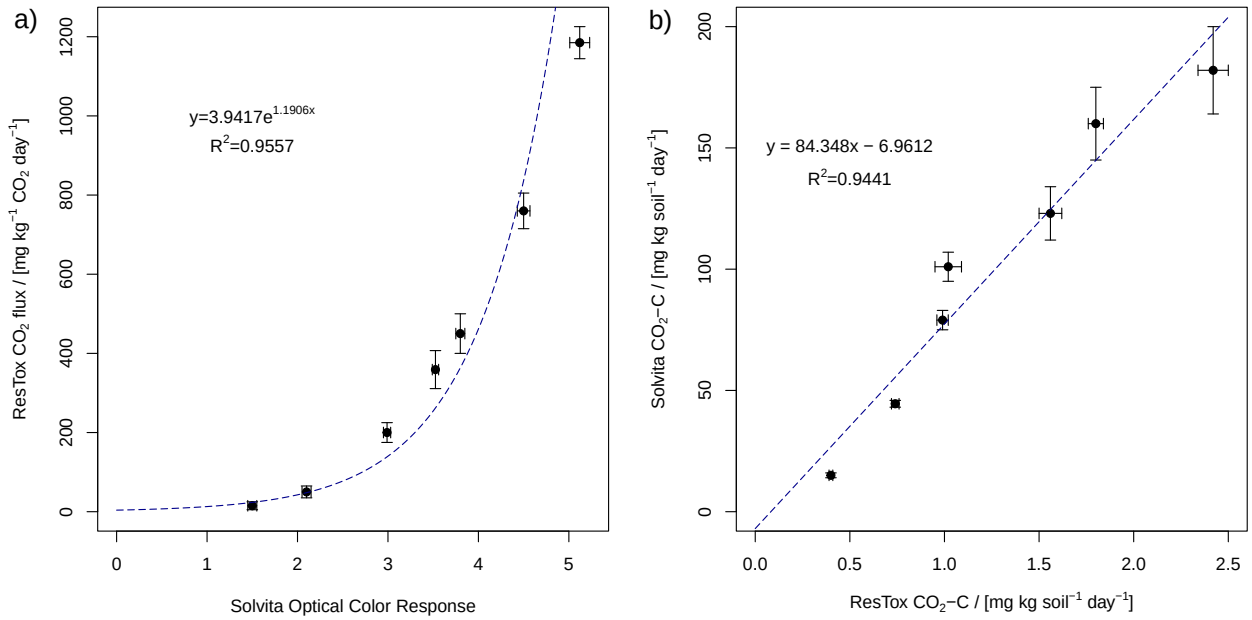

Figure 4: The relationship between Solvita optical color response and CO2 flux measured using the ResTox system (a) and CO2-C as determined using the Solvita soil respiration test system and the ResTox system (b).

Price comparison of the tested systems

In addition to comparative measurements, we also compared the prices of the tested systems (Tables 1 and 2). Unit prices of the ResTox system components were retrieved from online stores from which the parts were purchased.

Table 1: Prices of ResTox system components.

ResTox components	Price / [$]
Arduino Mega 2560 Rev 3	39
SEN0220, MH-Z16 Intelligent Infrared Gas Module (x9)	846
DS18B20 Digital Waterproof Temperature sensor	7
Phototransistor Light Sensor	1
Main protective case	8
Cables and other consumables/supplies	50
Filaments used for 3D printing	30
TOTAL	**981**

Table 2: Prices of Solvita sensor system components.

Solvita soil respiration test system components	Price / [$]
Digital Color Reader – Multi-Mode Unit	1749
Basic Soil CO2-Burst kit (9 Pack with PS Jars)	195
CO2-Burst Test Refill (per CO2 probe; price depending on quantity: 25, 50 or 100 probes)	13.16-9.89
TOTAL (excluding CO2-Burst Test Refill)	**1944**

References

Brinton, W., Vallotton, J. (2019) Basis for Comparisons of Soil CO2 Respiration Test Procedures, Letters to the Editor, Agricultural & Environmental Letters, 4:1, doi:10.2134/ael2018.10.0053

Solvita (2016) Soil CO2 burst official method version 2016.1. Woods End Laboratories, Mt. Vernon, ME.